# Serge Hoogendoorn

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With over 25 years of experience in the field of smart mobility, Serge has built up substantial experience in a diverse range of subdisciplines, including traffic flow theory, multi-modal traffic management, data collection, and AI.

TU Delft

# The Transformative Role of AI in the Mobility domain

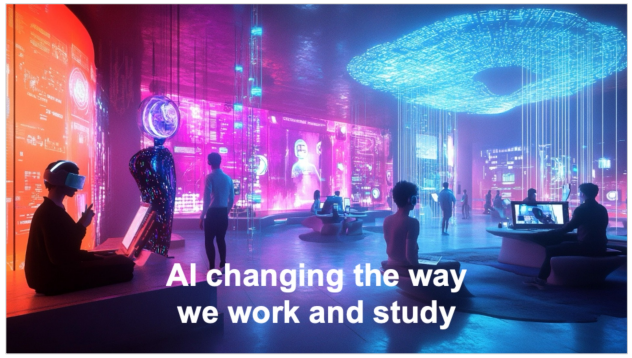
Prof. dr. Serge Hoogendoorn

08-05-2025

# Not another AI talk!?

**A talk about what AI means for mobility — and for us: as students, academics, and professionals…**

# Transformative role of AI in the mobility domain?


## Transforms our system

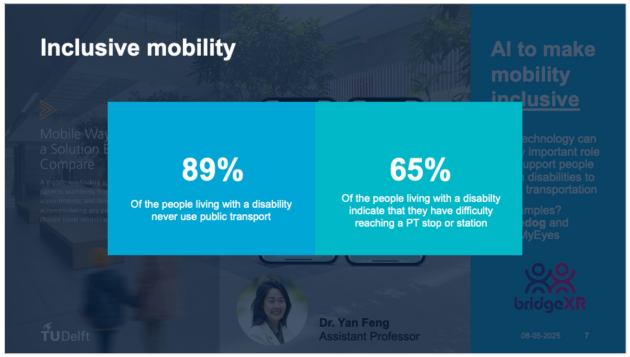
AI fundamentally **changes the system** that we are studying (understanding) and influencing

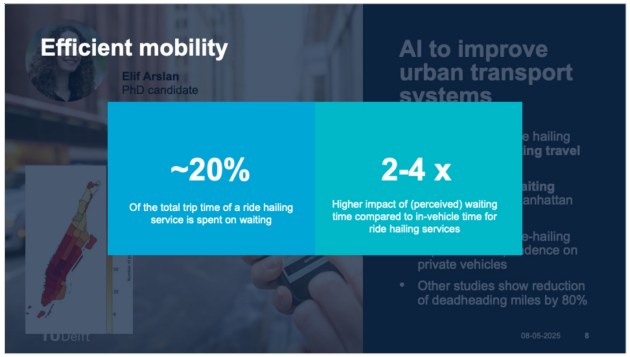
## Transforms ‘us’

AI changes **how we study, do research and work** and what skills we need


AI could radically change the transportation system

# Two examples




## Inclusive mobility

Supporting people living with disabilities in their daily travel

## Efficient mobility

Making transportation services more efficient using AI

# Inclusive mobility

**89%**

Of the people living with a disability never use public transport

**65%**

Of the people living with a disabilty indicate that they have difficulty reaching a PT stop or station

**Dr. Yan Feng**
Assistant Professor

TUDelft

bridgeXR

# Efficient mobility

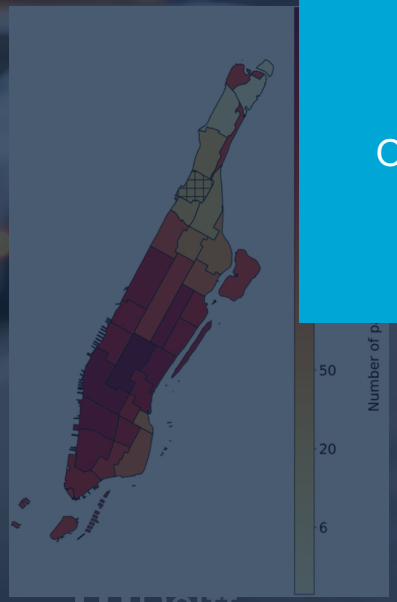
**Elif Arslan**
PhD candidate

**~20%**

Of the total trip time of a ride hailing service is spent on waiting

**2-4 x**

Higher impact of (perceived) waiting time compared to in-vehicle time for ride hailing services




## AI to improve urban transport systems

e hailing
**ing travel**

**aiting**
anhattan

e-hailing
ndence on
private vehicles

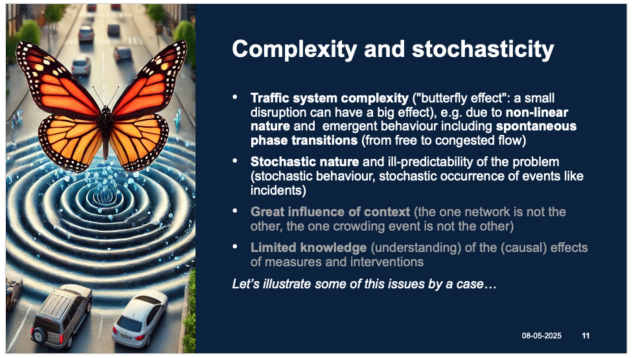
- Other studies show reduction of deadheading miles by 80%

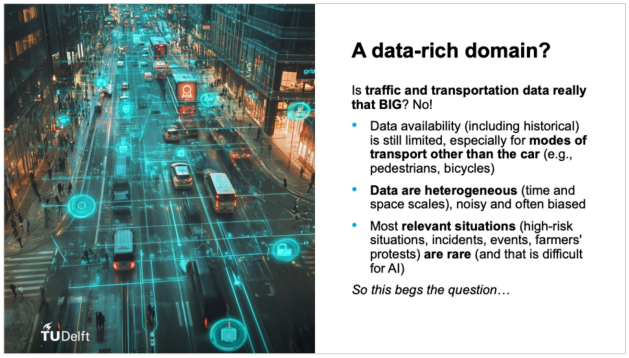
# My 1st proposition

**The uptake of AI in the TTE domain has been slow…**

… hampering solving many of the societal challenges in traffic and transportation

# Challenges AI in Traffic & Transport Engineering





## Complexity

Traffic and transportation systems are complex and ill-predictable

## Big data revolution?

Mobility data are often biased, erroneous, not representative, etc.

## Role of ethics

Trust, human autonomy, transparency play major role in traffic and transportation

# Complexity and stochasticity

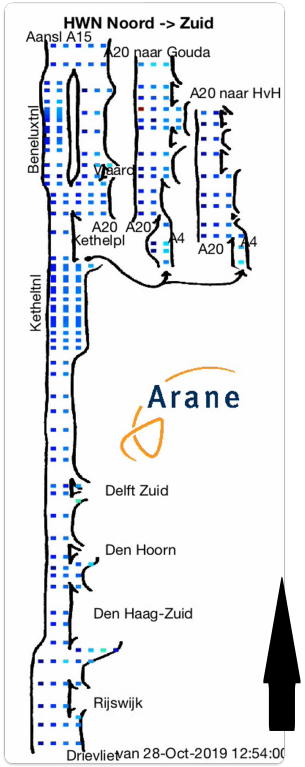
- **Traffic system complexity** ("butterfly effect": a small disruption can have a big effect), e.g. due to **non-linear nature** and emergent behaviour including **spontaneous phase transitions** (from free to congested flow)
- **Stochastic nature** and ill-predictability of the problem (stochastic behaviour, stochastic occurrence of events like incidents)
- **Great influence of context** (the one network is not the other, the one crowding event is not the other)
- **Limited knowledge** (understanding) of the (causal) effects of measures and interventions

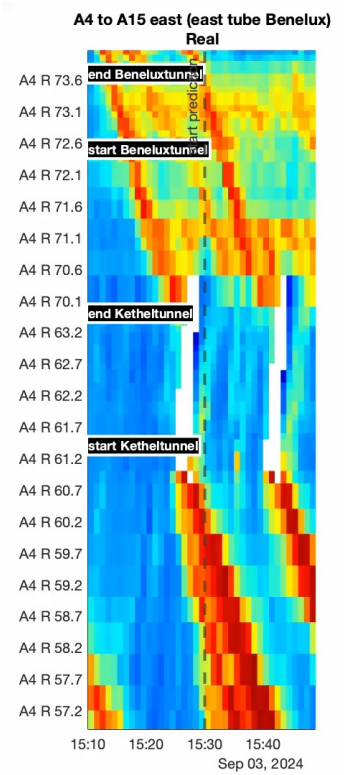
*Let's illustrate some of this issues by a case…*

To ensure traffic safety, **queuing in the Ketheltunnel has to be prevented**: when congestion spills back, the tunnel is closed based on current traffic situation.

When that occurs, queuing starts upstream of the tunnel substantially reducing the tunnel throughput due to the capacity drop phenomena.

# Predicting short-term traffic conditions



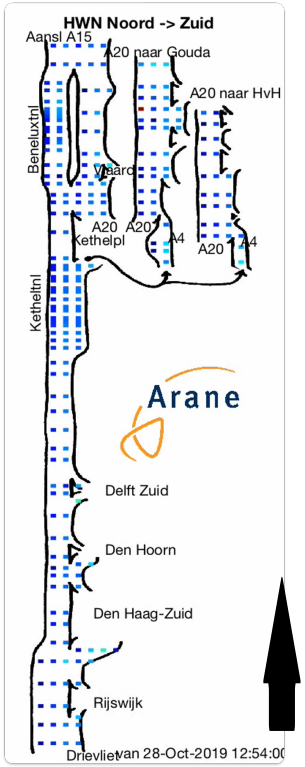



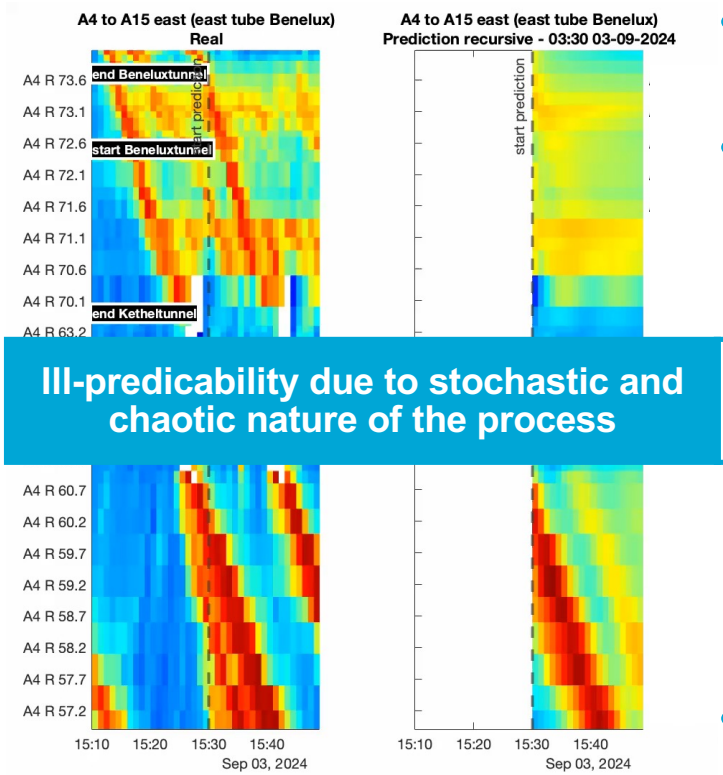

- Picture / animation provides overview of the loop observations in and around the tunnel
- **Speed contour plots** shows how:
  - high-density waves on freeway move in the downstream, direction through the tunnel
  - When the queue reaches the tunnel, the tunnel is temporarily closed, and the queue is moved to the upstream entry of the tunnel

*Research objective?*

- Test **multi-step Deep Learning method** for short-term prediction (30 min ahead) for network wide traffic management purposes where we focus on preventing the tunnel metering to activate

# Predicting short-term traffic conditions

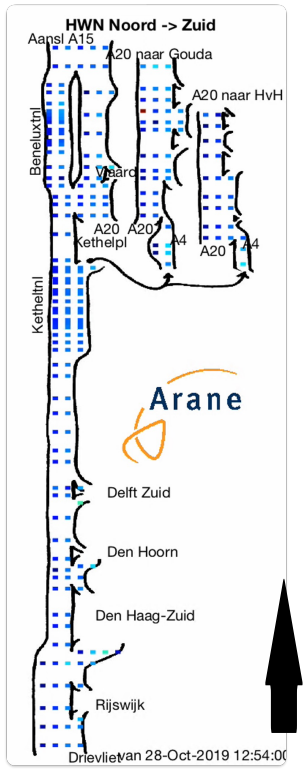


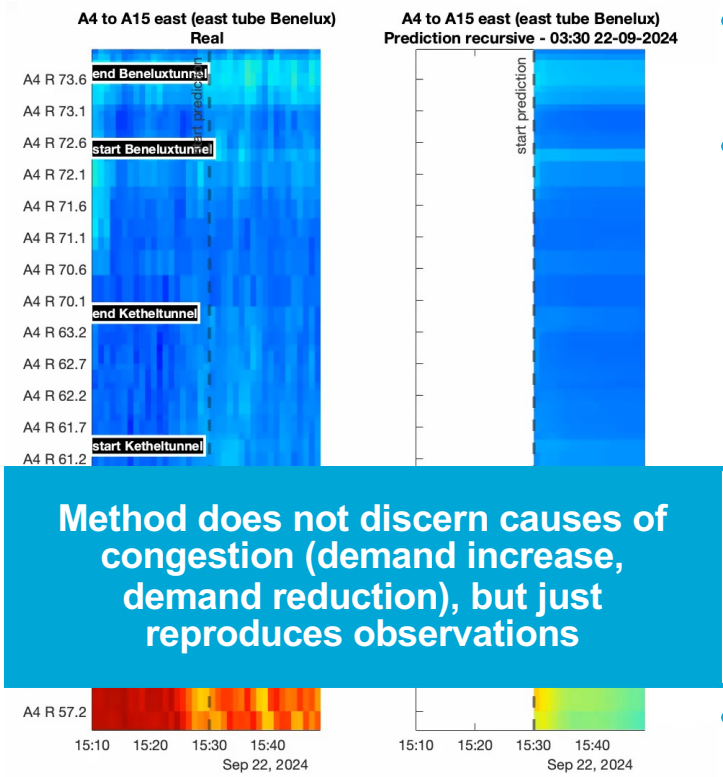




**Ill-predicability due to stochastic and chaotic nature of the process**

- Animation shows development of 30 minute ahead predictions
- Deep Learning model **succeeds in** picking up general traffic operations patterns (e.g., shockwave propagation) but **fails** on several aspects:
  - Start of congestion is often missed (initiation of the shockwave)
  - Situations that show change in demand (e.g., weekend) or supply conditions (e.g., roadworks) are not reproduced
- **Limitations impact applicability!**

# Predicting short-term traffic conditions




**Method does not discern causes of congestion (demand increase, demand reduction), but just reproduces observations**

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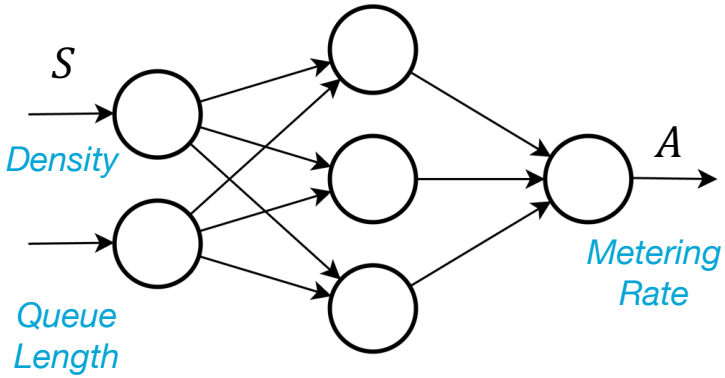
My 2nd proposition:

**In Traffic and Transportation Engineering, application of AI requires proper integration of data science and domain knowledge**

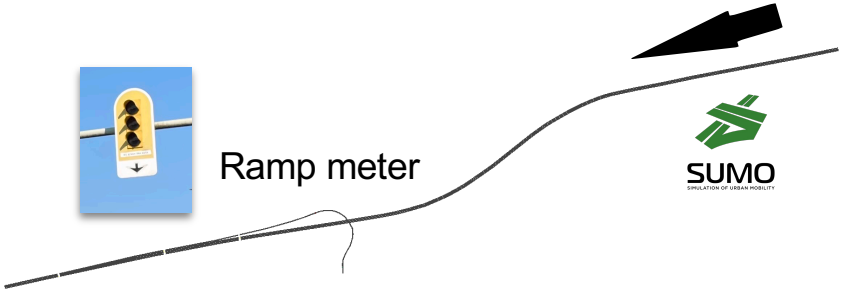
Two examples…

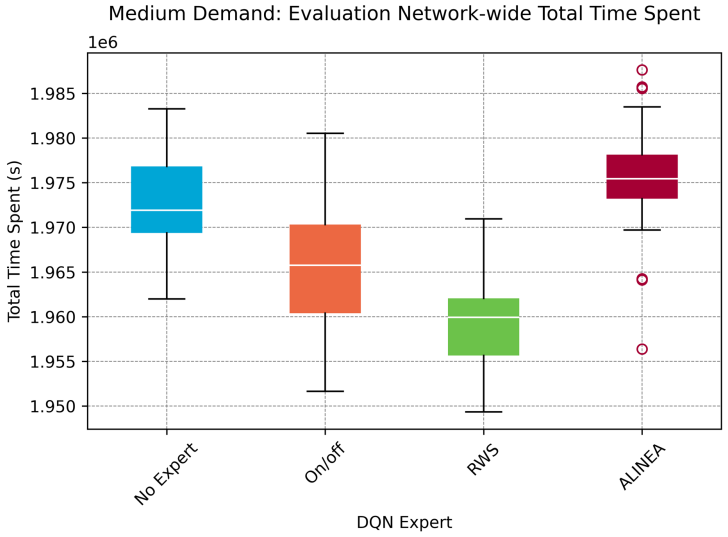
# Deep Reinforcement Learning




- DRL has been proposed as a powerful AI method for a variety of control tasks including **ramp-metering**, but has yet to prove their value idue to very slow tuning
- Objective: include **expert (= domain) knowledge** (i.c., existing control methods, such as ALINEA or RWS) by pre-training: speeds up tuning and improves performance (see picture)
- Current work looks at how **expert knowledge** can be included  for network coordination

**Callum Evans**
PhD Candidate

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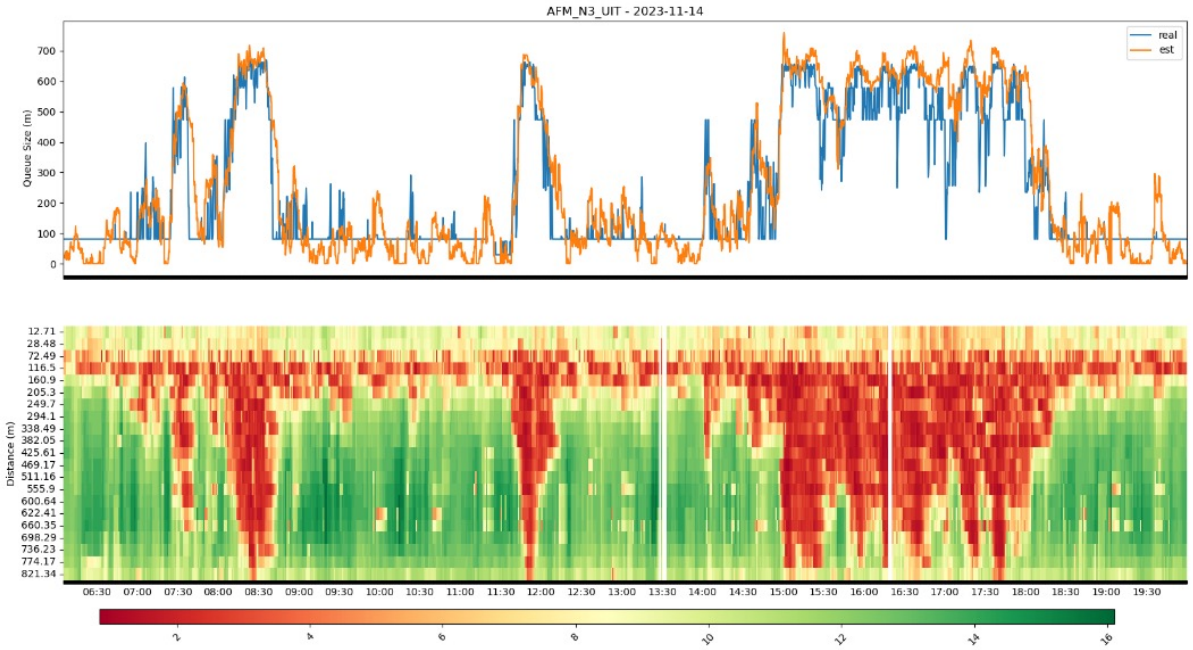
# Queue estimation for real-time traffic control

- Notoriously difficult problem in traffic engineering as queues **cannot be directly observed**
- Real-time queue lengths are needed for many control algorithms (e.g, Max Pressure for queue balancing; ALINEA and RWS for queue protection)
- Recent work focusses on **AI-supported Kalman filters**, effectively combining traffic flow models with powerful AI
- Example application Rotterdam

**Ting Gao**
PhD Candidate

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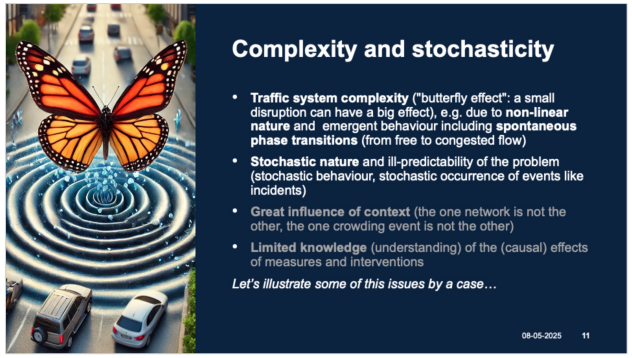
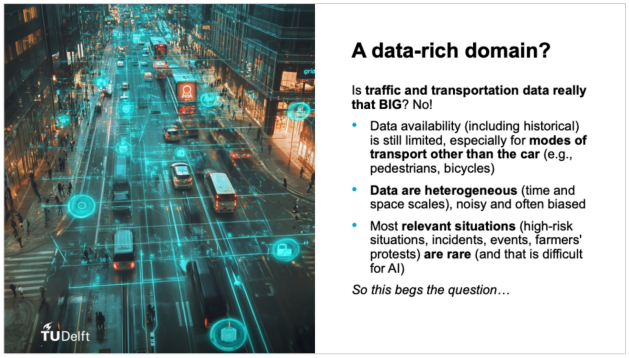
# Challenges of applying AI in traffic & transport?





## Complexity

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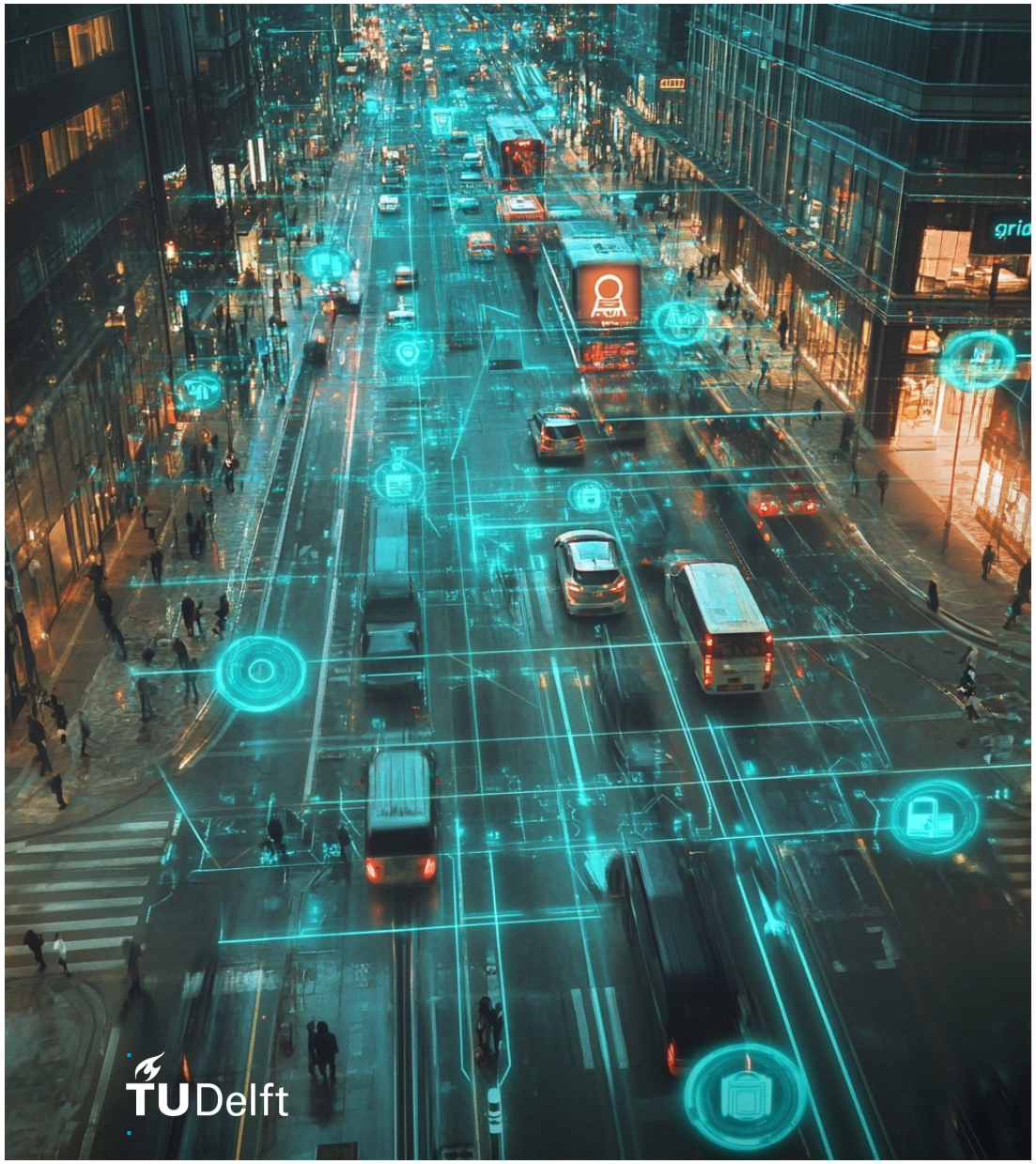
## Big data revolution?

Mobility data are often biased, erroneous, not representative, etc.

## Ethics

Trust, human autonomy, transparency play major role in traffic and transportation

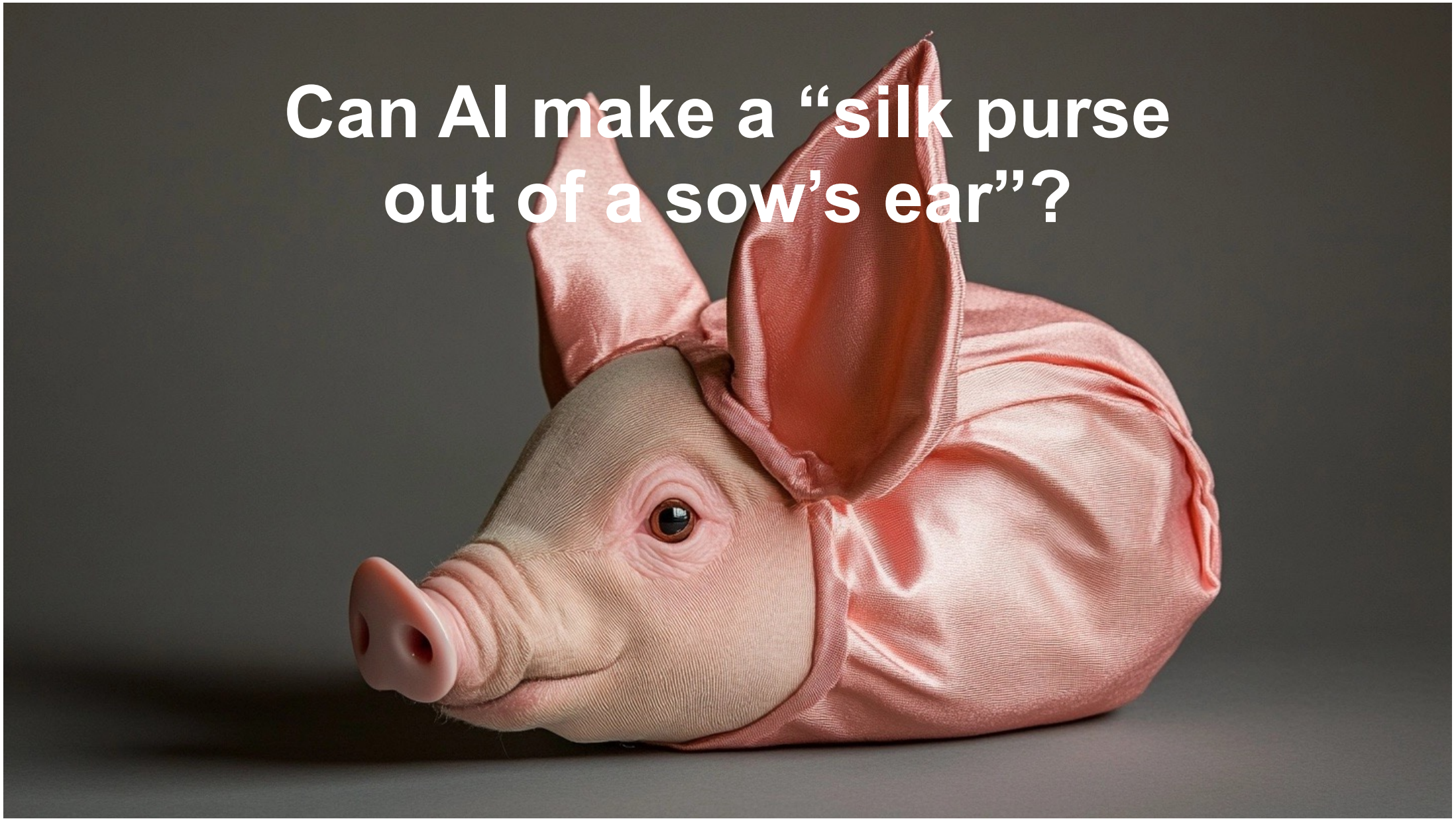



# A data-rich domain?

Is **traffic and transportation data really that BIG**? No!

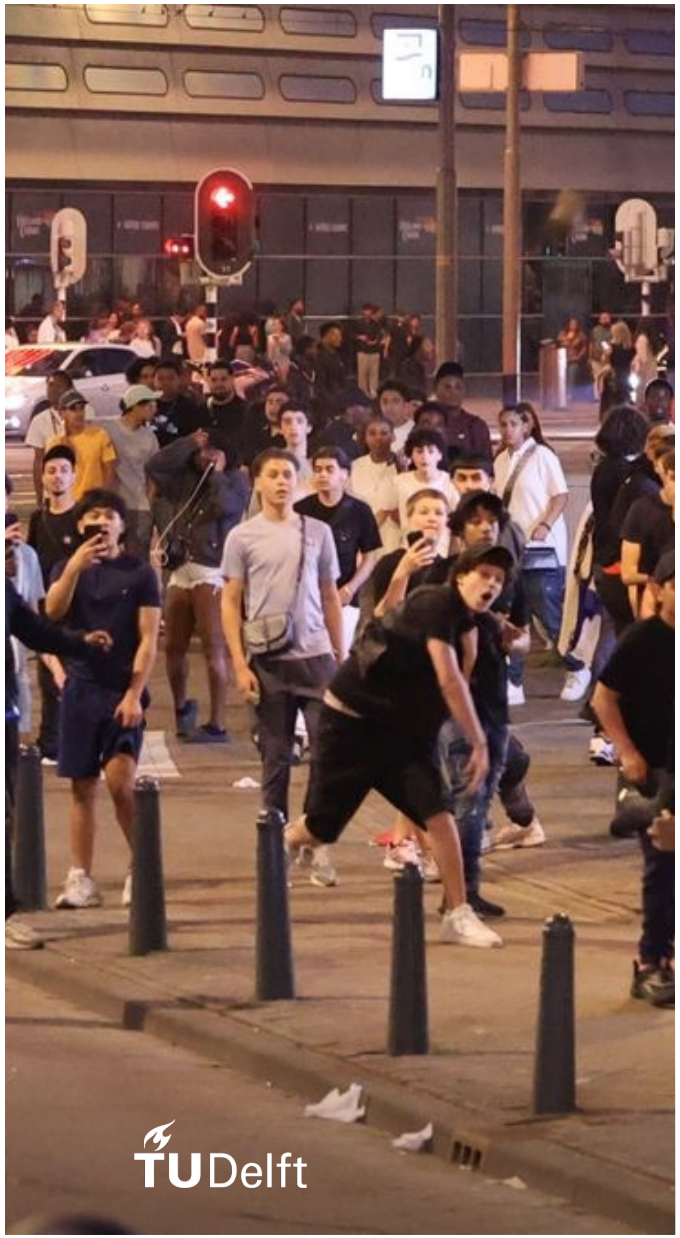
- Data availability (including historical) is still limited, especially for **modes of transport other than the car** (e.g., pedestrians, bicycles)
- **Data are heterogeneous** (time and space scales), noisy and often biased
- Most **relevant situations** (high-risk situations, incidents, events, farmers' protests) **are rare** (and that is difficult for AI)

*So this begs the question…*


Can AI make a “silk purse
out of a sow’s ear”?

The **Crowd Safety Manager** is a decision support platform for crowd managers that brings together and visualises relevant sources of data, combines these data (**data fusion**), predicts crowding conditions (**prediction and forecasting**) and asseses risk


Op initiatief van POLITIE Den Haag



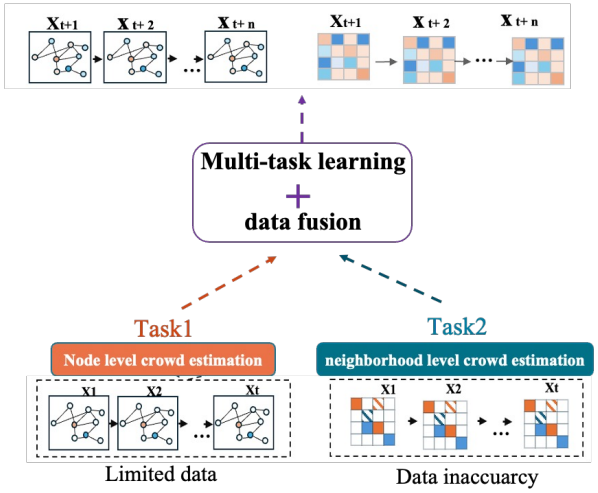

# CSM and AI

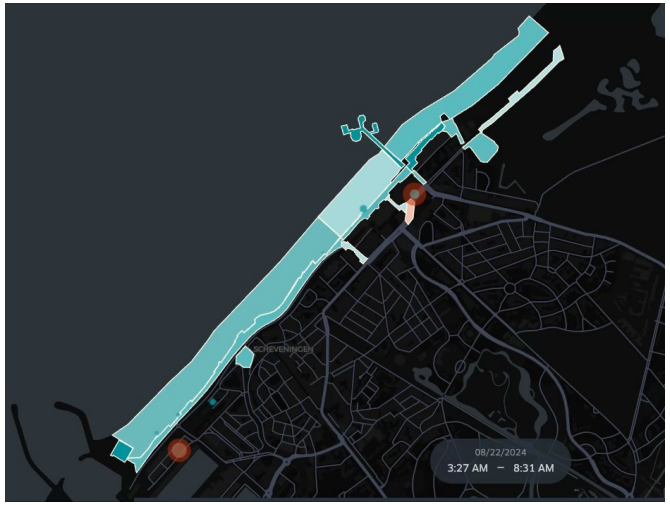
- For the **Crowd Safety Manager (CSM), none** of the available datasources provides a comprehensive or accurate picture of crowding:
  - **Resono data** stems from smartphones: available everywhere, but biased + low granularity (spatial)
  - **Cameras** provide density, speed, flow: low bias, accurate, but local and sparse
  - **GooglePOI data**: available at many locations, low temporal granularity (1 hour resolution)
- Key challenges?
  - Can AI be used to improve our data (remove bias, increase accuracy)?
  - Can we predict high risk situations reliably?

# Data fusion by multi-task machine learning

Test use of AI for data fusion to remove bias and improve spatial and temporal granularity:

- Animation shows unbiased crowdedness levels on a region level at various locations
- Hourly Google POI data has been further disaggregated to 5 min level by capitalising on temporal resolution of region data sources (Resono)

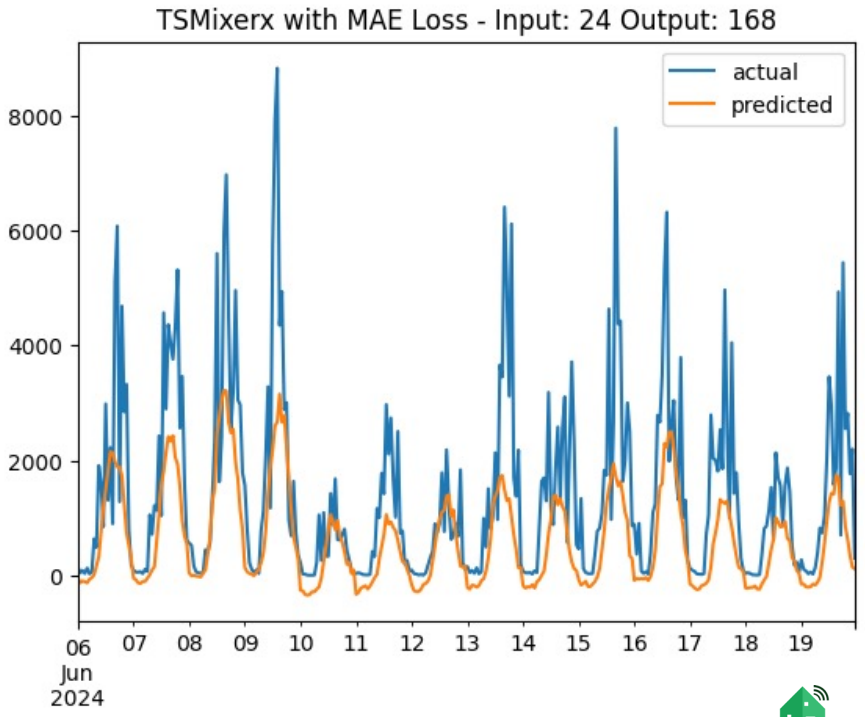



**Yanyan Xu**
PhD Candidate

# Impact of non-representative data

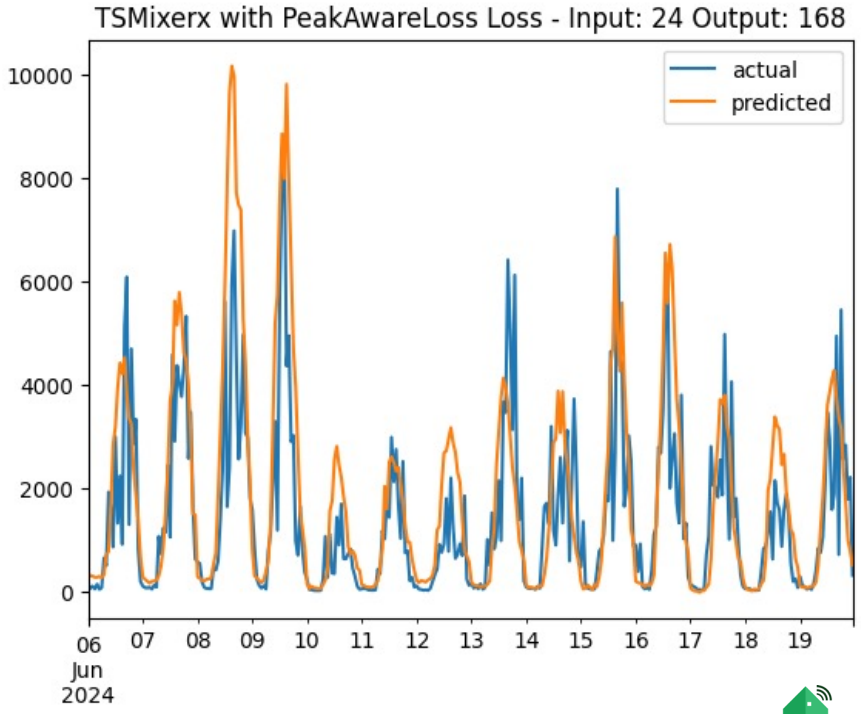
- Aim to predict crowdedness several days ahead to support **planning** and **real-time crowd management**
- Deep Learning methods seem suitable for this task, yet application of ‘off the shelve’ AI technology does not result in useful outcomes: **peaks are structurally underestimated**
- **What is the main issue?**
  - Data contains mostly information on situations that are not crowded, nor risky
  - Training ML methods using these data provides predictions that are on average good, but do not reflect peaks well



# Non-representative data and prediction impact

- Define new **loss function** that allow for appropriate prediction of **peak hours** and **peak days**:
  - Higher weights for peak periods (‘peak boost’)
  - Penalize underprediction to reduce the chance that we predict too small crowds and arrange for too few support staff

**Theivaprakasham Hari**
PhD Candidate

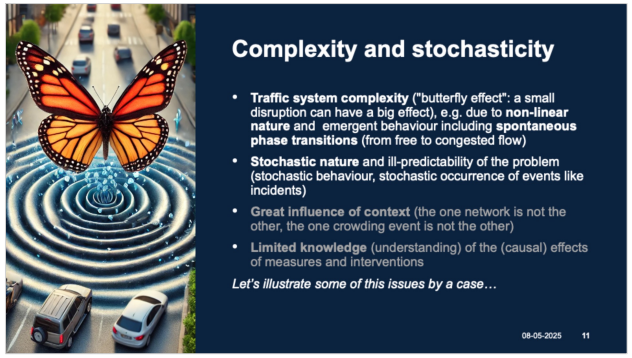


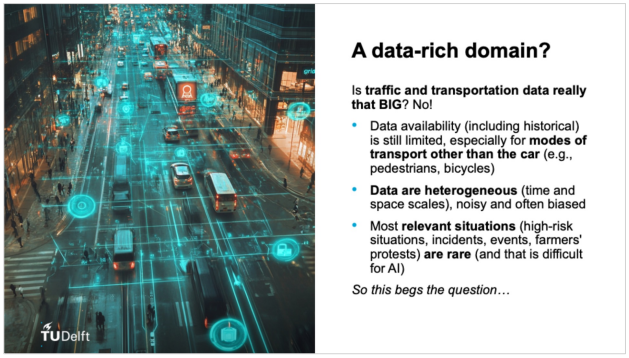
# Future steps CSM

- Five year project AICOMPASS sponsored by NWO
- AI providing **information** to crowd managers and planners about **risk**
- AI providing **optimized advice** to the crowd managers and planners (what to do?)
- See AI as a member of a **hybrid team of humans and machines:** what the key issues involved?

AiCompass

# Challenges of applying AI in traffic & transport?





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## Big data revolution?

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## Ethics

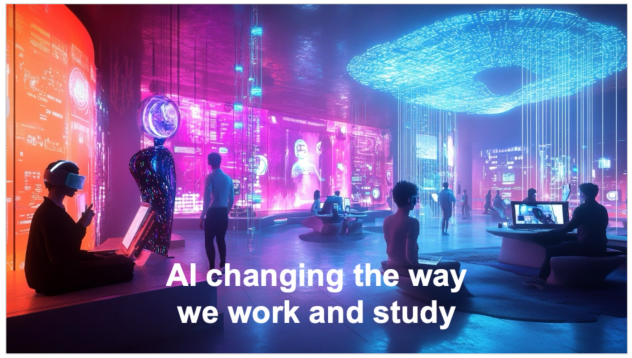
Trust, human autonomy, transparency play major role in traffic and transportation


# From trust to overreliance on AI?

- Distrust in AI relates to limited **understanding of how AI works:** how is advice is determined (transparancy, explainability)?
- **Human autonomy in decision making**, aiming to prevent over-reliance on automated systems and maintaining human oversight
- Risk of echo chambering for both humans and machines

*These issues highlight the importance of explainable AI, but ever more so the role of training and education!*

# Transformative role of AI in the mobility domain?


## Transforms our system

AI fundamentally **changes the system** that we are studying

## Transforms ‘us’

AI changes **how we study, do research and work** and what skills we need


AI changing the way
we work and study

# AI transforms how we work…

- AICOMPASS looks at the **future role** of AI  in a ‘human – machine’ teams
- But AI is already changing the way we work (and study!) **now:**
  - Performs simple office tasks, does our reporting
  - Provides us with better information, catered to our needs
  - Support planning, design, and optimisation tasks
  - Eventually provides complex decision support

# TTE engineers (need to) change!

*The future Traffic and Transport Engineer needs complementary skills (technical and soft):*

- In 2023, 65% of transport/logistics employers said digital skills outweigh formal degrees
- By 2030, a **global shortage of 250,000+ AI-skilled professionals** in mobility is expected
- Projections for the US show that 44% of tasks are automatable; but **only 12% of transport planning jobs may disappear** as roles shift

# Will we be obsolete?

Well, there are some counterarguments:

- **Model collapse:** AI being trained by AI generated data eventually results in plateau
- **Impact of domain knowledge** in understanding and improving AI
- AI (still?) seems to lack creativity

Next to human autonomy, several other risks can be identified (loss of system understanding, reinforcement bias, and automation lock-in) if humans become complacent…

My final proposition:

**As long as ChatGPT is not able to tell a decent joke, we are okay!**

AIC4NL

# Together towards Responsible Applications of AI

A learning community that applies AI for a safer, more efficient and more inclusive mobility system

AiMTT

AI Learning Initiative for Multi-modal Traffic and Transportation

TU Delft

Lab

Digitisation & AI for
Mobility Network Dynamics

# Questions and Answers

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08-05-2025